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RESEARCH ARTICLE

Productivity of Cassava (*Manihot esculenta* crantz) varieties in Gena Bosa district of Dawuro Zone, South-western Ethiopia

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Abstract

Limited varieties are among the major factors that limit cassava production in Ethiopia. Therefore, afield experiment was conducted in the Mela and Bodisub-districts of Gena Bosa district in Dawro Zone during 2017 cropping seasons, to determine the growth response of cassava varieties. The treatments consisted of four varieties (Local, Variety, Kello and Awassa-04 varieties) and two locations (Mela and Bodi sub-district). The experiment was laid out as a randomized complete block design (RCBD) and replicated three times per treatment. Data were collected on phenology, growth, yield components and yield. The data were subjected to analysis of variance. The results indicated that interaction effect of variety and locations were significantly affected crop phenology, growth, yield components and yield. Awassa-04 variety planted both at Mela and Bodisub-district significantly improved phenology, growth, root morphology, yield components, and root yield of cassava. The average root yield of cassava obtained in Awassa-04 variety planted at Mela sub-district about 46.5% exceeded the average root yield obtained from local cassava planted at Bodi sub-districts. The highest mean net benefit (162,880 ETBha^{-1}) with an acceptable marginal rate of return of 3,460% was obtained fromAwassa-04 variety. Thus, planting Awassa-04 variety is suggested for maximize the agronomic and economic returns of cassava farmers in the study area.

Keywords: Economic analysis; Growth; Root morphology; Yield components; Root yield.

1. Introduction

Cassava (*Manihot esculenta* crantz) global production is about 278 million metric tons in 2021, out of which Africa's share was about 61% (FAOSTAT, 2022). According to FAO projections, by 2025, about 62% of global cassava production will come from sub-Saharan Africa (FAOSTAT, 2020). Cassava is one of the major root crops grown in the lowlands of Ethiopia (Amsalu, 2003). Currently, root crops occupy0.9% of the area cultivated to other crop types (248,357.51 hectares) in the country (CSA, 2022). Cassava is among the most widely cultivated crops in lowland areas of Wolaita and Dawro Zones in South western Ethiopia (Kebede *et al*., 2012; Mulualem *et al*., 2013).

Cassava root plays a significant role in human food and the leaf for livestock fodder (Biruk, 2013). In Gena Bosa district in South western Ethiopia cassava is among the major root and root crop in area and root yield production. According to GBDADO (2017) cassava occupies 56% of the area of land allotted to the production of root and root crops. However, farmers harvest a lower average yield (23.5 t ha^{-1}) than the cassava yields can obtained under optimal conditions (80 t ha^{-1}) (Howeler *et al*., 2013; FAO, 2018).

Limited improved varieties are serious problems constraining cassava productivity in Ethiopia (Legese *et al*., 2011). In most cases, farmers in Dawuro Zone plant local cultivar (GBDADO,

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2017). The problem resulted for lover cassava productivity in the study area. Shadrack *et al*. (2017). also indicated that verity related problems are major yield-limiting factors of cassava. In the meantime Legese *et al*. (2011) reported that limited improved varieties significantly influenced the root yield of cassava at Hawassa in South western Ethiopia. The limitation of improved cassava varieties requires immediate attention for sustaining production and productivity of crops in smallholder farms in the study area.

Planted variety is the major determinant factor for higher root quality and productivity (Sukmadjaja *et al*., 2011). Also, reports in Ethiopia have shown that improved varieties increase root yield about 89% than local cultivar (Misganaw *et al*., 2020). This is due to the genetic potential of improved varieties, which enable to have higher root yield (Mulualem *et al*., 2012). In this regard, the most districts in Dawuro Zone are used the local cultivars (Bilate *et al*., 2022). Confirming this problem, Berhanu*et al*. (2023) reported that limited varieties are the major factor constraining cassava root yield production in Dawuro Zone. Thus, the survival, growth, and root yield of cassava are highly affected in study area due to a lack of improved varieties (Daemo*et al*., 2023). The studies in many parts of Ethiopia indicated improved varieties significantly improved root yield of cassava than local cultivar (Daemo *et al*., 2023; Legese *et al*., 2011; Legese, 2018; Tadesse *et al*., 2017). However, limitation in planting improved cassava varieties and inadequate information about the improvement root yield of improved varieties. In this study, it was hypothesized that the variety planted and planting position improve root quantity and quality of cassava. Therefore, this research was conducted to evaluate the combined effects of cassava variety on the productivity of cassava in Gena Bosa district in Dawuro Zone, Southwestern Ethiopia.

(*Citrus limon* L.) is the most prominent member of the Rutaceae families. People throughout the world used lemon as Vitamin C sources, cleaning and cooking (Shamsi *et al.,* 2016; Paciolla *et al.,* 2019). Through 2020 a bout of 21.4 million tonnes of lemons and limes were produced globally, 80% of all postharvest losses during storage period (Calavan *et al.*, 1989). The most harmful postharvest pathogens of citrus fruits are *Penicillium digitatum* and *Penicillium purpurogenum* (Steiner *et al.*, 1994; Ismail and Zhang, 2004;) *Talaromyces purpurogenus* fungus formerly known as *Penicillium purpurogenum* (Samson *et al.*, 2011). Among the most promising alternatives to synthetic fungicides is biological control (Wilson and Chalutz 1989). Citrus postharvest infections can be efficiently prevented by a variety of yeast antagonists. (Chalutz and Wilson, 1990; Arras, 1996; Taqarort *et al.*, 2008). Several commercial biological control formulations based on *Trichoderma harzianum*, *Bacillus subtilis*, and *Gliocladium virens* (Spadaro and Droby, 2016; Liu *et al.,* 2019). Struggle for nutrients and available space is thought to be the primary mechanism of action (Filonow, 1998; Spadaro *et al.,* 2004). Additional proposed mechanisms of action include antibiosis, increased resistance, and the production of lytic enzymes (Janisiewicz and Korsten, 2002). In order to improve the effectiveness of the antagonists and provide screening criteria for new isolates, a fuller understanding of their mechanism of action is essential. Therefore, the purpose of this research was to isolation, identification of the lemon soft rot pathogen which widespread during limon harvest season morphology and molecularly. The ability of *T. harzianum*, *Saccharomyces cerevisiae* and *Candida oleophila*, on suppressed the linear growth of *Talaromyces purpurogenus in* vitro was assessed as the first step in the pathogen biocontrol.

2. Materials and methods

2.1. Description of the Experimental Site

The study was conducted during the 2017 main cropping seasons on farmers' training center of Mela and Bodi sub-district of Gena Bosa district in Dawuro Zone, South western Ethiopia.

The study site was selected purposively based on its high cassava production potential. The experimental site is located at 07°01'00" N latitude and 37°14'00" E longitude, and an altitude of 2355 meters above sea level (Mathewos *et al.,* 2013). In the 2017 cropping seasons, the mean monthly temperatures of Mela and Bodi sub-districts ranged from 15 °C to 30.5 °C and from 14.5 °C to 28.8 °C, respectively with annual rainfall of 1,187 mm and 1376 mm, respectively. (NMA, 2018). The dominant soil type in both the study areas is Nitisols (Mathewos *et al.,* 2013).

2.2. Experimental Materials

2.2.1. Planting material

The experiment was includedQule, Kello and Awassa-04 cassava varietieswere obtained from Hawassa Agricultural Research Center and local cultivar used as control treatment. These varieties were selected based on their agro-climatic requirements (900–2600 ma.s.l), which suited with the study area(Wondimu *et al*., 2023).

2.3. Treatments and Experimental Design

The treatments consisted of four varieties (Local, Variety, Kello and Awassa-04 varieties) and two locations (Mela and Bodi sub-district). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times per treatment. The plot size was 4.5 m x 4.5 m (20.25 m^2) with 1 m spacing between plots and 2 m between blocks. The inter-row and intra-row spacing was90 and 90 cm, respectively, and each row and plot consisted of 6 and 36 plants, respectively (Legese *et al*., 2011).

2.4. Experimental Procedures

The experimental field was ploughed three times using a traditional oxen-drawn *maresha* followed by manual root-bed preparation method and laid out according to the experimental design. The middle part of the main stem, which had 25 cm length and at least with four buds were burned and compacted (Legese *et al*., 2011). Planting was carried out in 08 April 2017 following the onset of rainfall. Weeds were removed by hand weeding after crop emergence up to harvesting. Harvesting was done manually using hand digging tool as done locally by cassava farmers. The crop was harvested on 18 June 2017.

2.5. Data Collection and measurement

2.5.1. Phenological data

Data on the number of days to bud sprouting was recorded starting from the date of planting until 50% of the plant population in the plot exhibited visible buds. However, the number of days to physiological maturity was recorded from the date of planting to when 90% of leaf of the cassava plant stands in a plot changed to a yellow color.

2.5.2. Growth data

All growth data were recorded from five randomly selected plants from the central rows at harvest. Plant height was measured from the base to the tip of the plant by using a measuring tape. The numbers of primary and secondary branch were determined by counting all branches originating from the main stem and secondary branch, respectively. The number of buds per plant was counted buds sprouted from all stem.

2.5.3. Root morphological data

Data on the root morphology of the cassava consisted of all parameters, which contributed to a change in the external structure of the root of cassava plants. In the meantime, all morphological data were recorded from five randomly selected plants at the flowering stage harvest from the central rows of each plot to keep the uniformity of the effect of uprooted plants on yield. Prior to measuring the root length, number of roots per plant and root diameter, root samples carefully dig out. The root length of longest root per plant was measured from the base to the tip of the root by using a measuring tape. The number of roots per plant was counted after the soil clods were carefully removed. Root diameter was recorded by using a digital caliper by attaching it to the center of a stem.

2.5.4. Yield components and yield data

Total root yield, marketable and unmarketable root yield were determined by weighing the fresh weight using a sensitive balance at harvest.

Marketable root yield (t ha^{-1}): It was calculated by weighing all the roots which were free from defects, disease, crack, and other physiological disorders and not underweight per net plot area and converting into ton per hectare(Tesfaye *et al*., 2013).

Unmarketable root yield (t ha^{-1}): Roots which were damaged, diseased and insect pest attacked, undersized (<30mm), misshaped, decayed was considered as unmarketable.

Total root yields (t ha^{-1}): It was calculated as the sum of the weights of marketable and unmarketable roots from the net plot area and transformed to ton per hectare.

2.6. Data Analysis

Homogeneity of variances was tested using the F-test as described by Gomez and Gomez (1984). Since the F-test showed homogeneity of the variances of the two location for most of the agronomic parameters, a combined analysis of variance was done using SAS version 9.4 (SAS institute, 2013) following the procedure described by Gomez and Gomez (1984). The treatment means were separated using the Least Significant Difference test at a 5% level of significance.

2.7. Partial budget analysis

Partial budget analysis was done as described by CIMMYT (1988). All varieties and labor for planting positions were considered to analyze the partial budget of the cassava. Since root is important for farmers, the partial budget analysis considered the mean marketable root yields of each treatment in the 2017 cropping seasons. Economic analysis was done using the prevailing market prices for inputs at planting and outputs, at the time the crop was harvested. The costs of varieties were based on the market price of Hawassa agricultural research center in Southern Ethiopia. All costs and benefits were calculated on a hectare basis in Ethiopian Birr (ETB). Total costs that varied (TCV) included the sum of the costs incurred for purchasing of varieties, transporting, and planting. The costs were estimated from market and farm gate prices. The costs of purchasing local, Qule, Kello and Awassa-04 cassava varieties was 8 birrBirr kg^{-1}, 12 birr Birr kg^{-1}, 12 birr Birr kg^{-1} and 12 birr Birr kg^{-1}, respectively. The average local market price of cassava was 8 birrBirr kg^{-1} in 2018cropping year. For a hector of land 300 kg cassava cutting was planted. Actual root yields were adjusted downwards by 10% to reflect the difference between the experimental yield and the yield farmers would expect to get from the same treatment. Then the net benefit (NB) is calculated as the difference between the gross benefit (GB) and the TCV (CIMMYT, 1988). The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique are referred to as dominated and un-dominated treatments, respectively. The un-dominated treatments ranked from the lowest to the highest cost. For each pair of ranked treatments, the percentage marginal rate of return (MRR) was calculated. The MRR percentage between any pair of un-dominated treatments was the return per unit of investment in variety. To obtain an estimate of these returns, the percentage MRR was calculated as changes in NB divided by changes in TVC. A treatment, which was non-dominated, and having an MRR of greater or equal to 50% and the highest net benefit said to be economically profitable (CIMMYT, 1988). However, Getachew and Rezene (2006) suggested an MRR of 100% as realistic in our country. Thus, for this study, 100% and above return to the investment was considered as a reasonable minimum acceptable rate of return.

3. Results and discussion

3.1. Crop Phenology

3.1.1. Days to flowering

The duration in the number of days required by the plant to reach 50% days to bud sprouting was significantly (P<0.05) influenced by the main and interaction effects of varieties and location.

Interaction of varieties and location resulted in significantly varying numbers of days required to reach 50% days to bud sprouting of cassava (Table 1). In this regard, delaines to reach days to 50% bud sprouting in local cultivar both at Bodi and Mela sub-district. However, early sprouting observed in Awassa-04 variety at both locations (Table 1). This result shows that local cultivar prolonged days to bud sprouting whereas improved varieties shortened it. Overall, the early and late bud sprouting of cassava obtained on Awassa-04 variety planted and local cultivar planted at both locations, respectively. Thus Awassa-04 variety planted at Bodi sub-district reduced the days to bud sprouting by 6 days than local variety that planted in the same location. This may be associated with the genetic potential of improved varieties than local cultivar (Howeler *et al*., 2013). In addition, relatively higher temperature at Bodi reduces the days to bud sprouting than Mela (Table 1). This result shows that low temperature delayed bud sprouting, whereas an increased temperature hastened it. The result is consistent with the natural tendency of increased temperature toreduce the days to phonologic parameters of the plants. The result is consistent with the findings of Misganaw and Bayou (2020) who reported different days to 50% days to bud sprouting in the same varieties in different locations at Fafen District in Ethiopia.

Table 1. Interaction effect of varietieson days to 50% bud sprouting and days to 90% of physiological maturity cassava in Gena Bosa district, Southwestern Ethiopia in 2017 cropping seasons.

Varieties	Days to 50% DBS		Days to 90% DPM	
	Location		Location	
	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district
Local	17.78b	19.56a	403.56bc	409.56a
Qule	15.33d	16.78c	401.56c	406.78abc
Kello	16.56c	18.22b	403.78bc	408.22ab
Awassa-04	13.89e	15.33d	401.22c	405.33abc
LSD (5%)	0.97		5.72	
CV (%)	3.93		9.5	

*Means in column and rows followed by the same letter are not significantly different at P = 0.05 according to Fishers Protected LSD test. ns = Not Significant; *,**,*** significant at p < 0.05,0.01,0.001, respectively; DBS = Days to bud sprouting, DPM = Days to physiological maturity.*

3.1.2. Days to physiological maturity

Days to physiological maturity of cassava was significantly (P < 0.05) influenced by the main and interaction effect of varieties and location.

The number of days required by cassava to reach physiological maturity varied from 401 to 410 days in response to the interaction effect of varieties and location. Thus, the lowest numbers of days required by the plant to reach physiological maturity were recorded for the interaction of Awassa-04 variety planted at Bodi sub-district. On the other hand, the longest days required to reach maturity by the plant were recorded all varieties planted at Mela sub-district (Table 1). Thus, late maturity in local cultivar planted at Mela sub-district due to favorable soil and environmental condition that resulted for delayed maturity in cassava (Sukmadjaja and Widhiastuti, 2011).

3.2. Growth Parameters

3.2.1. Plant height

The height of cassava plants varied significantly ($P < 0.05$) in response to the main and interaction effects of varieties and location. The highest plant height of cassava recorded all varieties that planted at Bodi sub-district than Mela sub-district (Table 2). The highest cassava height was obtained at Qule variety that planted at Mela, which is statistically equivalent with local and Awassa-04 varieties planted at the same location. Whereas, the lowest plant height of cassava recorded on Awassa-04 variety planted Bodi sub-district. Thus, Qule variety that planted at Mela sub-district resulted in 11.07% more height than Awassa-04 variety planted Bodi sub-district (Table 2). Growth of the tallest cassava in Qule variety that planted at Mela could be associated with the synergic role of adaptable variety and suitable location. Since, it promoted cell division, growth, and differentiation (Narmilan and Puvanitha, 2020). Because of the cumulative role of varieties and soil nutrients variability in each location attribute for cell division, cell expansion, and enlargement, this might have ultimately contributed to growth in plant height of cassava. Consistent with this result, Wondimu *et al.* (2023) reported that Qulle variety resulted in 85.5 cm more height than Awassa-04 variety.

3.2.2. Number of buds

The number of bud was significantly ($P \leq 0.01$) affected by main and interaction effect of varieties and location.

The highest and lowest number of bud was recorded at interaction of Awassa-04 variety planted at Mela sub-district and local cultivar planted at Bodi sub-district, respectively (Table 2). Thus, Awassa-04 variety planted at Mela sub-district resulted in about 28.5% larger number of bud than local cultivar planted at Bodi sub-district. The result might be associated with the combined role of variety and location. The results are consistent with that of Shami *et al*. (2017), who reported Qulle variety resulted in about 18 % larger number of bud than local variety at Tappi, South Western Ethiopia. Wondimu *et al*. (2023) also reported that all improved varieties resulted in a considerably branches than the local cultivar.

3.2.3. Number of primary branches per plant

The number of primary branches per plant responded significantly ($P < 0.01$) to the main and interaction effects of varieties and location.

The highest number of primary branches per plant was obtained at Awassa-04 variety planted at Mela, which is statically equivalent with Kello and Qule varieties planted at Mela sub-district. On the other hand, the lowest number of primary branches per plant was obtained on local cultivar planted at Mela and Bodi sub-districts (Table 2). The results of this study indicated that variety and location alone would not lead to the maximum number of primary branches per plant. However, the interaction of variety and location led to a significantly higher number of primary branches per plant. Since, the soil nutrient contain varies location to location and plants that received sufficient nutrient typically exhibit vigorous plant growth that is attributed to the number of the branch (Sukmadjaja and Widhiastuti, 2011). On the other hand, the number of primary branches varied as per the variety planted. Whereas, the combination of suitable planting position with appropriate variety facilitates healthy growth and increased the number of branches per plant (Polthanee and Wongpichet, 2017). In line with this result, Shadrack *et al*. (2017) indicated interaction of variety and location highly influenced the number of branches per plant of cassava.

Table 2. Interaction effects of varietiesand location on growth parameters of cassava in Gena Bosa district, Southwestern Ethiopia in 2017 cropping seasons.

Varieties	PH		NB		NPB	
	Location		Location		Location	
	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district
Local	254.11c	276.99a	32.33e	34.67cd	3.44e	4.22de
Qule	255.11c	278.09a	33.5de	35.89c	5.11cd	6.44ab
Kello	253.44cd	276.26ab	35.56c	38.22b	5.56bc	6.78a
Awassa-04	251.11d	273.72b	38.89b	41.56a	5.56bc	6.89a
LSD (5%)	2.56		1.28		1.09	
CV (%)	6.4		2.37		13.37	

*Means in column and rows followed by the same letter are not significantly different at P = 0.05 according to Fishers Protected LSD test. ns = Not Significant; *,**,*** significant at p < 0.05,0.01,0.001, respectively; PH = Plant height, NB=number of buds, NPB=number of primary branch.*

Table 3. Interaction effects of varieties and location on root morphologic parameters of cassava in Gena Bosa district, Southwestern Ethiopia in 2017 cropping seasons.

Varieties	Root length		Root diameter		Number of roots per plot	
	Location		Location		Location	
	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district
Local	78.11e	84.37d	3.67d	5.00c	4.67e	5.33e
Qule	84.22d	90.94c	4.67cd	6.11b	6.67d	7.78bc
Kello	85.44d	92.27c	5.67bc	7.56a	7.89bc	8.89a
Awassa-04	100.56b	108.61a	5.67bc	7.44a	7.44cd	8.44ab
LSD (5%)	3.01		1.09		0.90	
CV (%)	2.23		12.76		8.52	

*Means in column and rows followed by the same letter are not significantly different at P = 0.05 according to Fishers Protected LSD test. ns = Not Significant; *,**,*** significant at p < 0.05,0.01,0.001, respectively; RL= root length, RD= root diameter, NRPP=number of roots per plant.*

3.3. Root Morphology of Cassava

3.3.1. Root length

The main and interaction effect of varieties and location significantly (P < 0.05) influenced the root length. The root length might be associated to planted variety and availability of sufficient nutrient in each location. For instance, maximum root length was produced in response to Awassa-04 variety planted at Mela sub-district; whereas the minimum root length obtained on local cultivar planted at both Bodi and Mela sub-districts (Table 3). The maximum root length achieved in aforementioned treatment due to maximum vegetative growth in Awassa-04 variety and in which the root length increased to balance root to shoot ratio (Wondimu *et al.*, 2023). Also the slant planting position and the soil textural class at Bodi might contribute for root perforation and elongation. In line with this finding Shamil *et al.* (2017) reported the tallest root length on local cultivar than improved varieties at Southwestern Ethiopia.

3.3.2. Root diameter

The root length was significantly (P < 0.01) affected by the main and interaction effect of varieties and location. The widest root diameter was recorded in Kello and Awassa-04 varieties planted at Mela sub-district; whereas, the narrowest obtained local and Qule varieties that planted at Bodi sub-district (Table 3). Thus, Kello and Awassa-04 varieties planted at Mela sub-district were 50% higher root diameter than that of local cultivar that planted at Bodi sub-district (Table 3). The results clearly show the cumulative effect of varieties and location high effect on root diameter. Since, the root diameter directly associates with the variety and the soil fertility status of planted location. Particularly nutrient deficiency, promotes the production of more roots per plant as an adaptation mechanism to low nutrient supply than resulted for narrow root diameter (Fageria and Jones, 2011). This suggestion is consistent with the proposition of Legesse (2018) that interaction effect of varieties and location significant influence on the diameter of cassava at Amaro southern Ethiopia.

3.3.3. Number of roots per plant

The main and interaction effect of varieties and location significantly (P < 0.05) influenced the number of roots per plot. There is no discernable trend was observed in the number of roots per plant in the response to varieties and location (Table 3). Thus, Kello variety planted at Mela sub-district higher number of roots per plant, which was statistically parity with Awassa-04 variety planted in the same location. On the other hand, the lowest number of roots per plant local cultivar planted both at Bodi and Mela sub-districts (Table 3). Thus, Kello variety planted at Mela sub-district lead to the production of 4 more number of roots per plant than local cultivar planted at Bodi sub-districts (Table 3). This result may indicate the cumulative effect of genetic potential of Kello variety and suitability of planting location enhanced the number of roots per plant at Mela sub-district. Since the number of roots per plant directly correlated with planted cassava variety (Wondimu *et al*., 2023) and the variety planted (Abdoulaye *et al*., 2014). Also fertile soil promotes thenumber of roots per plant (Fageria and Jones, 2011). Furthermore, some studies conducted in a different part of Ethiopia had shown improved variety increase the number of roots per plant of cassava (Misganaw and Bayou, 2020; Mulualem and Ayenew, 2012; Mulualem and Dagne, 2015; Shadrack *et al.*, 2017; Shamil *et al.*, 2017). Overall, this study noted that the cumulative effect of improved varieties and the soil fertility status of planed location increased the number of roots per plant of cassava.

3.4. Yield components and yield

3.4.1. Unmarketable roots

The main and interaction effects of varieties and location significantly (P<0.01) influenced unmarketable roots (Table 4).

Higher unmarketable roots were obtained in local cultivar that planted both at Bodi and Mela sub-district. Conversely, lowest unmarketable root were produced in all improved varieties that planted both at Bodi and Mela sub-district (Table 4). For example, unmarketable roots obtained in local variety that planted at Bodi sub-district exceeded the mean unmarketable roots produced in all improved varieties that planted both at Bodi and Mela sub-district by 57.9%. This signifies the local variety is, in fact, had many defects and planting of improved varieties is required to reduce the amount of pods per unmarketable roots. Similar results were obtained by Wondimu *et al*. (2023), who reported higher amount of unmarketable roots local cassava cultivar. Furthermore, Abdoulaye *et al*. (2014) also reported lower unmarketable roots due to local cassava cultivar.

Table 4. Interaction effects of varieties and location on yield and yield components parameters of cassava in Gena Bosa district, Southwestern Ethiopia in 2017 cropping seasons.

Varieties	Unmarketable roots		Marketable root yield		Total root yield	
	Location		Location		Location	
	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district
Local	2.65a	2.05ab	15.78f	17.19e	17.89e	19.20d
Qule	1.67b	1.61b	18.33d	19.99c	20.00d	21.57c
Kello	1.78b	1.72b	18.44d	20.09c	20.22d	21.79bc
Awassa-04	1.67b	1.62b	21.22b	23.12a	22.89b	24.72a
LSD (5%)	0.62		0.95		1.15	
CV (%)	23.44		3.32		3.69	

*Means in column and rows followed by the same letter are not significantly different at P = 0.05 according to Fishers Protected LSD test. ns = Not Significant; *,**,*** significant at p < 0.05,0.01,0.001, respectively; UNMR= Unmarketable roots, MY= marketable yield, TRY= Total root yield.*

3.4.2. Marketable roots

The marketable root significantly ($P < 0.01$) affected by the main and interaction effect of varieties and location.

The marketable roots were higher in Awassa-04 variety planted at Mela sub-district and lover in local cultivar planted Bodi sub-district (Table 4). Thus, the highest marketable roots were recorded at Awassa-04 variety planted at Mela sub-district about 46.5% more than the marketable roots obtained from the local cultivar planted Bodi sub-district (Table 4). The results of this study indicated that planting of improved cassava variety at right place would lead to a higher marketable root. In agreement with this result, Sukmadjaja and Widhiastuti (2011) reported significantly higher marketable roots in response to slant position.

3.4.3. Total root yield

The total root yield significantly ($P < 0.01$) influenced by the main and interaction effect of varieties and location.

The improved varieties significantly and consistently increased total root yield of cassava than local cultivar in both locations (Table 4). Thus, the highest total root yield of the crop was obtained in response to Awassa-04 variety planted at Mela sub-district. On the other hand, the lowest total root yield was produced in response to local cultivar planted at Bodi sub-district (Table 4).

Table 5. Partial budget analysis of cassava influenced by varieties and planting position in Gena Bosa district, South western Ethiopia in 2017 cropping seasons.

Varieties	Unadjusted Marketable yield (t ha^{-1})		Adjusted Marketable yield (t ha^{-1})		Gross Field Benefit (ETB ha^{-1})		Total Variable Costs (ETB ha^{-1})		Net Benefit (ETB ha^{-1})		Marginal Rate of return (%)	
	Location		Location		Location		Location		Location		Location	
	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district	Bodi sub-district	Mela sub-district
Local	15.78	17.19	14.20	15.47	113,600	123,760	2,400	2,400	111,200	121,360	-	-
Qule	18.33	19.99	16.50	17.99	132,000	143,920	3,600	3,600	128,400	140,320	1,433	1,580
Kello	18.44	20.09	16.60	18.08	132,800	144,640	3,600	3,600	129,200	141,040	1,500	1,640
Awassa-04	21.22	23.12	19.10	20.81	152,800	166,480	3,600	3,600	149,200	162,880	3,167	3,460

This total root yield obtained on Awassa-04 variety planted at Mela sub-district exceeded about 38.2% than local cultivar planted at Bodi sub-district. The improved cassava planted in the right place may have experienced high rates of photosynthesis and typically exhibit vigorous plant growth that contributed to total root yield in cassava (Sukmadjaja and Widhiastuti, 2011). Overall, the enhanced production of total root yield in cassava in response to the improved varieties could be attributed to the physiological roles in plant growth and total root yield. This implies that the suitable combination of improved cassava variety and favorable place fulfilled the growth requirements of the plants through synergic effects (Narmilan and Puvanitha, 2020). Consistent with this result, Abdoulaye *et al.* (2014) reported planting of improved variety increased the total root yield of cassava by 34.7% than a local cultivar. Similarly, Shamil *et al.* *(*2017) also showed a 11% improvement in total root yield of cassava due to planting of Kello and Qule varieties than local cultivar.

3.5. Partial budget analysis

The maximum net benefit of 162,880 ETB $ha^{-1}$was recorded at Awassa-04 variety at Mela sub-district. The result is followed by Awassa-04 variety planted at Bodi sub-district. (149,200 ETB ha^{-1}**)** (Table 5). However, the minimum net benefit of 111,200 ETB $ha^{-1}$and 73,116 ETB ha^{-1}were gained on local cultivar planted horizontally at Bodi sub-district (Table 5). Overall, the economic analysis revealed the highest net benefit (162,880 ETBha^{-1}) with an acceptable MRR (3,460 %) Awassa-04 variety at Mela sub-district (Table 5). The economical net gain at Awassa-04 variety at Mela sub-district was about 46.5% higher than local cultivar planted at Bodi sub-district (Table 5). The possible reason for the higher economical net gain at Awassa-04 variety planted at Mela sub-district could be associated with higher economic yield gained due to the suitable combination of variety and location, which enhances the net profit. Thus, Awassa-04 variety is suggested for the higher mean net benefit of cassava growing farmers in the study area.

4. Conclusion and Recommendations

The results of this study demonstrated that the phenology, growth, root morphology, yield components, and root yield were significantly influenced by the interaction of variety and planting location. A maximum marketable cassava root yield of 23.12t $ha^{-1}$was recorded inAwassa-04 variety planted at Mela sub-district. However, the lowest marketable cassava root yield (15.78t ha^{-1}) was recorded for local cassava planted at Bodi sub-district. Overall, the root yield produced in Awassa-04 variety planted at Mela sub-district is about 46.5% higher than the root yield obtained in local cassava planted at Bodi sub-district. In general, for a better root yield (23.12 t ha^{-1}) and the highest mean net benefit (162,880 ETB ha^{-1}) with an acceptable marginal rate of return (3,460%), farmers in the study area are advised to plant Awassa-04 variety. Therefore, this finding suggests that to plant Awassa-04 variety to maximize the agronomic and economic returns of the crop for enhanced food security, higher income, and improved livelihood of cassava farmers in the study area.

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